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(E75-10053) WATER SURVEY OF CANADA: APPLICATION FOR USE OF ERTS-A FOR RETRANSMISSION OF WATER RESOURCES DATA Final (Department of the Environment, Ottawa) 27 p HC $3.75 CSCL 08H G3/43

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Proposal No. 532-G
SR No. 9629

CR-140959

Water Survey of Canada:
Application for Use of ERTS-A
For Retransmission of
Water Resources Data

R.A. Halliday

Applied Hydrology Division

Department of the Environment

Ottawa, Ontario, Canada

K1A 0E7

August, 1974

Type III Report for the Period July, 1972 - June, 1974

1. SR No.	2. Type of Report	3. Recipient's Catalog No.
9629	Type III	

4. Title Water Survey of Canada: Application for Use of ERTS-A for Retransmission of Water Resources Data	5. Report Date August, 1974 6. Period Covered July 1972 - June 1974
7. Principal Investigator R.A. Halliday	8. No. of Pages
9. Name and Address of Principal Investigators Organization Applied Hydrology Division, Department of the Environment, Ottawa, Ontario, Canada. K1A OE7	10. Principal Investiga.Rept.No 11. GSFC Technical Monitor George Ensor
12. Sponsoring Agency Name and Address As above.	13. Key Words (Selected by Principal Investigator) Data Retransmission, Water Resources Data, Data Collection Platforms, Canada.

14. Supplementary Notes

Report prepared by R.A. Halliday and I.A. Reid.

15. Abstract

Water resources data including water level, water velocity, precipitation, air temperature, ice condition, DCP battery voltage and water stage recorder clock operation have been transmitted from remote areas in Canada using the ERTS Data Collection System. The Data Collection Platforms have met all requirements.

The suitability of satellite retransmission as a means of obtaining data from remote areas has been demonstrated. The present network of 9 Data Collection Platforms will be expanded to 28 to develop a quasi-operational network.

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PREFACE

The objective of this investigation was to use ERTS Data Collection Platforms (DCPs) to collect water level readings and other related water resources data several times daily from each of nine gauging stations and to use this information for operational purposes. In this way, the dependability, costs and other aspects of the ERTS data collection system would be determined and decisions made with respect to the feasibility and advantages of establishing a much larger network of DCPs dependent on future satellite facilities.

Nine DCPs have been used to transmit water level data from sites in northern and western regions of Canada. Other data transmitted from some locations include precipitation, air termperature, water velocity, "ice-out" indication, DCP battery voltage, and water stage recorder operation check. Data were used both for water management purposes and for planning of hydrometric field activities.

The quantity of reliable data received far exceeded initial expectations. The DCPs proved very reliable; only one failed during the period covered by this report. The failure was a massive one and could be attributed only to a lightning strike or some other similar phenomenon.

On the basis of experience to date, it can be concluded that water resources data can be transmitted reliably at reasonable cost by satellite. The concept of an operational satellite retransmission system appears to be very attractive. Additional ERTS DCPs will be installed in 1974.

The original data discussed in this report were collected in the British system of units. Where possible, SI equivalents are shown.

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OBJECTIVES

When the ERTS Data Collection System (DCS) became available in 1972, it seemed worthwhile to investigate the possibility of using the ERTS DCS to collect discrete water level readings at least once daily from a few gauging stations and to use these data for operational purposes such as river flow and flood forecasting, water level forecasting for navigation, and planning of hydrometric field surveys.

To make a valid assessment with regard to reliability, costs and other aspects of the whole system, nine platforms were proposed for installation in remote areas of Canada. The sites were selected to give a wide range in climatic and areal conditions. Temperatures in the order of -50°C, wind velocities of 100 km/hr., or snow depths of 2m were possible at the sites selected. High temperatures, humidities or elevations were not a significant factor in this experiment.

Shortly after the data collection platforms were operational, it was apparent that the retransmission of data by ERTS-1 was highly successful. It was found that if invalid data were transmitted, the fault lay in the sensors or encoders. Because of this early success, it was decided to make more use of the data handling capability of the DCPs by transmitting additional useful parameters. Also, the Canada Centre for Remote Sensing (CCRS) made a strenuous effort to provide the data to users on a near real time basis.

TECHNIQUES

Deployment of DCPs

Since all the DCPs were intended for use in areas where site access was difficult and costly, it was decided to conduct a short test of each platform at a site in the City of Ottawa. One platform (I.D. 6137) did not operate during this test and was returned to General Electric for repairs. Table One lists the locations where the DCPs were installed

TABLE ONE.

LOCATION OF DATA COLLECTION PLATFORMS

I.D.	Station Name	Lat.	Long.	Activated	Sensors
6126	Duncan River below B.B. Creek	50° 38'	117° 03'	Oct. 25, 1972	Stage, Battery Voltage
6232	Nahatlatch River Below Tachewana Creek	49° 57'	121° 52'	Apr. 18, 1973	Stage, water velocity, recorder operation
6354	Illecillewact River at Greely	51° 01'	118° 05'	Sept. 6, 1972	Stage
	McGregor River at Lower Canyon	54° 14'	121° 40'	May 23, 1973	Stage
6260	Mackenzie River at Fort Simpson	61° 52'	121° 21'	Oct. 31, 1972	Stage, Ice movement
	Mackenzie River near Wrigley	63° 16'	123° 36'	June 7, 1973	Stage
6366	Mackenzie River at Norman Wells	65° 17'	126° 51'	Oct. 11, 1972	Stage, Ice movement
	Mackenzie River at Sans Sault Rapids	65° 46'	128° 45'	May 31, 1973	Stage
6150	Lake Athabasca at Crackingstone Point	59° 23'	108° 53'	Sept. 19, 1972	Stage, Battery voltage
6353	Kazan River at Outlet of Ennadai Lake	61° 15'	100° 58'	Sept. 19, 1972	Stage
6102	Albany River above Nottik Island	51° 38'	86° 24'	Jan. 13, 1973	Stage, precipitation, air temperature, ice movement
6137	Winisk River below Asheweig River Tributary	54° 31'	87° 14'	Feb. 21, 1973	Stage, ice movement.

and gives the date of the first transmission from the site. Platform 6102 was installed on the Albany River in October 1972, but did not transmit. The problem was traced to a loose connection to the antenna dipole at the time of the next visit to the location. It should be noted that three of the DCPs were moved to more strategic locations during the reporting period.

No particular problems were encountered in deploying the DCPs. Some persons carrying out the installation observed that the cardboard shipping container was too large to fit into a small aircraft or helicopter. This meant that the antennas had to be uncrated and handled without protection. Fortunately, none was damaged.

Photographs of some typical installations are included in Appendix I.

Sensors Used

Water Level

Water level is the primary parameter retransmitted from Water Survey of Canada gauging stations by ERTS-1. Two systems are used to sense water level. The first is a float and pulley operating in a stilling well that is connected to the river by intake pipes. Where it is not feasible to install or operate a stilling well system, because of climatic or economic reasons, a nitrogen purge system is used to sense the head of water above a fixed orifice near the river bed. The pressure of the head of water over the orifice is transmitted by the gas in the purge system to a servo-manometer (manufactured by CAE Aircraft) which converts this pressure to a shaft rotation. At conventional gauging stations, the output shaft from the servo-manometer or the float system is connected to a Stevens Type A analogue recorder. At the ERTS DCP sites, a Stevens Memomark II is used in conjunction with a float or servo-manometer to encode and store the water level as four binary coded decimal digits. This enables water levels ranging from 0000 to 9999 to be transmitted. Normally a precision of 0.01 ft. is used; in the metric system 0.002 m is adopted. No interface is needed between the Memomark II and the parallel digital connector on the DCP.

Precipitation and Air Temperature

In cooperation with the Atmospheric Environment Service (AES), Department of the Environment, a Hydrometeorological Automatic Recording and Telemetering System (HARTS) was installed at one site to encode and store data from a Fischer and Porter precipitation gauge and a platinum resistance bulb thermometer. Accumulated precipitation to the nearest 0.03 m (0.1 ft.) and temperature to the nearest 0.055C^{o} (0.1F^{o}) are encoded for transmittal by ERTS. The HARTS system is described in (Fong, 1973) and also has been used by the AES for encoding of snow pillow and wind run anemometer data for retransmittal by ERTS DCS. The HARTS unit is connected to the serial digital connector on the DCP.

Water Velocity

A record of water velocity at a point in a stream can provide a useful means of interpreting stage-discharge interactions during those times when the conventional stage-discharge relationship is not applicable. It has been demonstrated (Strilaeff and Bilozor, 1973) that stage and point velocity data can be used to compute reasonably accurate discharge data.

A March-McBirney two component electromagnetic water current meter having an output voltage of 0 to 1 volts corresponding linearly to 0 to 3 metres (10 feet) per second was installed at one ERTS DCP site. The output from the velocity meter was connected to two analogue channels on the DCP.

"Ice-Out" Indicator

A useful piece of information for computation of streamflow data and for planning of hydrometric operations is a knowledge of when the ice cover breaks up at a gauging station. Two sensors that use the same principle were designed to detect this ice movement. The first used a 4½ volt battery connected to light wire and whose voltage was transmitted using one of the analogue channels of the DCP. The battery was frozen into the ice surface of the river so that when the ice moved out, the cable would break and the voltage transmitted drop

to zero. A second version of the same system uses one bit rather than an entire word. In this case, a friction type plug is tied firmly near the water's edge with the male side of the plug shorted and connected to a line which is frozen into the ice. When the ice moves out, the plug pulls apart and the bit transmitted changes from a zero condition to a one condition. "Ice-Out" indicators have been installed at several sites.

DCP Battery Check

A battery check device (Kruus, 1973) has been installed at three sites to monitor the voltage level of the DCP power supply. The voltage of the DCP batteries is scaled to provide a voltage less than 5 volts. In order to conserve the DCP batteries, the device is switched on by the data gate signal prior to transmission. The battery check device uses one analogue channel.

Water Stage Recorder Operation Check

The Leupold & Stevens Type A recorder has very good cold temperature performance characteristics but is subject to clock stoppages at about -50^{o}C (Chapman, 1971). Also, the clocks stop once in a while for reasons other than cold temperatures. Once stopped, it is very unusual for a clock to restart on its own. A method of checking clock operation using a cam and single throw, double pole micro-switch was devised. When the recorder clock is operating, two parallel digital bits in the DCP message change from 01 to 10 to 01 and so on every 10 hours. A failure to change indicates that the recorder clock has stopped.

Table One shows the parameters transmitted by the DCPs.

Batteries

The DCP power is supplied by either two heavy duty 12 volt lead-acid batteries in series or 6 alkaline Union Carbide Number 564 batteries in series parallel. No problems have been encountered with either supply although batteries require charging annually.

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Air depolarized carbon-zinc batteries were also investigated as a DCP power source. One set will be installed in 1974.

Heating of Installations

As most of the DCPs were installed in regions where temperatures as low as -50^{o}C can occur, it was decided that some of the shelters housing the DCPs and sensors should be heated. (The water stage servo-manometer will not operate below -40^{o}C - the freezing point of mercury used in the system.) Two shelters that would be exposed to severe temperatures were not heated in order to check on DCP performance under these conditions.

To heat a shelter, an insulated compartment is constructed within the shelter using 6 mm (0.25 m) thick plywood and 50 to 100 mm (2 to 4 inch) thick expanded polystyrene beadboard insulation. The beadboard is glued to the plywood. Access doors are provided so that the sensors may be serviced. The enclosure is heated using a flame start Cata-Dyne BX3x4 catalytic propane heater equipped to provide an output of 200 kJ to 700 kJ an hour. Earlier models of this heater had a 630 kJ/hr. capacity thus exhausting the 45kg (100 lb.) propane supply after only 3 to 4 months of operation. Normally a 300-400 kJ setting will provide enough heat to ensure continuous instrument operation.

Field Test Set

One General Electric Field Test Set (FTS) was purchased for use with the Water Survey of Canada DCPs. Shortly after delivery, it was realized that the unit was mis-named. The FTS battery pack was poorly designed and tended to disintegrate under normal handling and shipping. Also, the FTS is much larger and heavier than the DCP itself thus making the unit difficult to transport. The complexity of the FTS tended to make the user mistrust the results. The unit showed that all 9 Water Survey of Canada DCPs were not operational. Eventually repairs were made to the FTS.

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It was decided that the FTS should only be used as a "depot test set". The only practicable way that DCPs can be serviced under Canadian field conditions is by replacement of the entire unit with one that is known to be in good order.

Data Handling and Processing

All ERTS Data Collection System products produced by NASA at the Goddard Space Flight Center that are destined for Canadian users are packaged and delivered to the Canadian Embassy in Washington, D.C. The data are then dispatched by diplomatic bag to the Canadian Department of External Affairs in Ottawa where the data are mailed to the Canadian Principal Investigators. This procedure usually results in a delay in receipt of data of about two weeks.

In order to receive near real time data, the Canada Centre for Remote Sensing (CCRS) in Ottawa and NASA made arrangements for Canadian DCS data to be received at CCRS by dedicated telephone line after each orbit. Normally a delay of 30 to 40 minutes is experienced. The data received are recorded simultaneously on a teletype hard copier and a magnetic tape. At present, these data are periodically (normally once daily) inputted to the CCRS time sharing computer system. A software data retrieval system sorts the user platforms, reformats the data into engineering units and stores individual user files on disk. The user may then access his data file using either a Teletype or Telex remote terminal. Several users across Canada receive data on a daily basis in this way.

As data transmitted in this manner are sometimes degraded, the data from the nine DCPs at Water Survey of Canada gauging stations that are received in card form from NASA are translated by computer into engineering units to provide a hard copy for comparison with data recorded in the field. Programmes were also prepared to generate some statistics on data received.

ACCOMPLISHMENTS

The most significant accomplishment has been a demonstration that retransmission of data on a near real time basis from isolated regions of Canada to users in major population centres by means of polar orbiting earth satellite is reliable, accurate and relatively inexpensive. It would not be economically feasible to install land line telemetry systems to obtain data from any of the nine sites where the DCPs are presently installed.

Data have been received on 3 to 8 orbits a day and as many as 20 messages a day have been received. Normally 7 to 16 messages are received daily, depending on the site. The quantity of data received seems to depend on the elevation angle of the horizon. Foliage in the vicinity of the antenna seems to have no affect while heavy, wet snow up to one metre in depth on the antenna ground plane has an almost negligible effect.

Sensor Performance

The sensors used by the DCPs generally performed well. Some water level data were lost because of clock problems in the Memomark II encoder. This General Electric clock does not seem to operate reliably at temperatures lower than -40°C. A more reliable clock has been ordered for installation in 1974.

The precipitation and air temperature HARTS unit provided good information and demonstrated the use of the HARTS system under severe weather conditions. This will be discussed in more detail in another Canadian Principal Investigator's report (Vockeroth).

Information from the water velocity sensor has not proved too useful since velocities tended to be low thus making the need for an integrator evident. Also the electromagnetic probe in the river was destroyed by ice action during the winter of 1973-74. The system will be re-activated in 1974 using integrated readings.

The "ice-out" indicators operated well especially the digital version. Figure one shows a record of the water level at one gauging station produced by a servo-manometer system. The ERTS transmissions are

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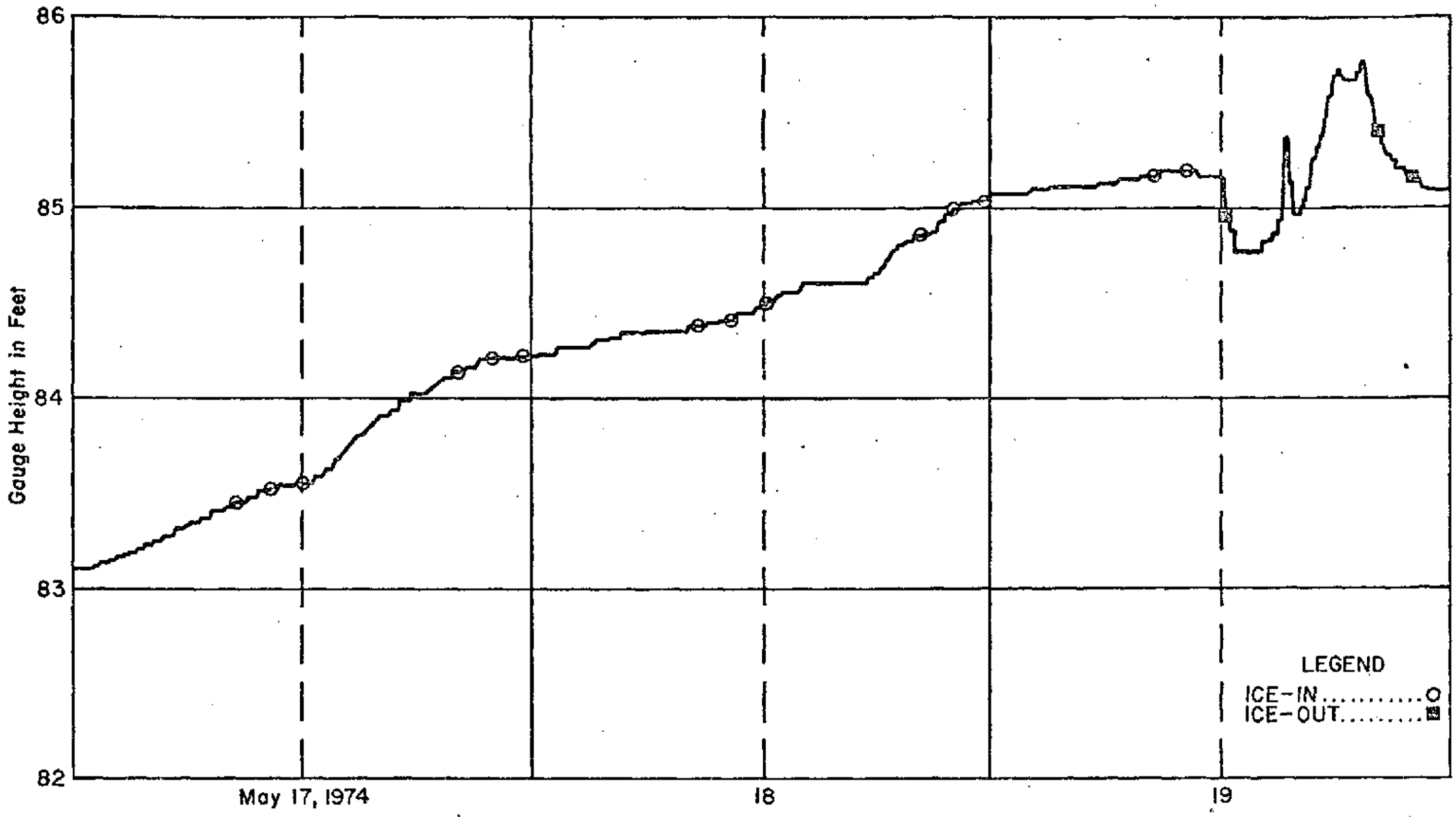

FIGURE 1. TRACE OF ALBANY RIVER ABOVE NOTTIK ISLAND
WATER LEVEL RECORDER CHART, MAY 17 to 19, 1974

marked on the figure. Note the smooth increase in water level caused by increasing flow when the indicator signifies that the ice surface is intact and the sharp drop in level immediately before the indicator signifies ice breakup. The subsequent erratic changes in water level after that time reinforce the belief that the ice did in fact break up during the period depicted in the figure.

The DCP battery voltage sensors also worked well although in one case it seemed as if the sensor was not turned on by the data gate signal. Replacement of the sensor showed that the problem lay in the sensor itself. Details of this will be contained in another Canadian Principal Investigator's report (Kruus, SR532).

The analogue water stage recorder clock operation check also worked well. A clock stoppage was detected and the information transmitted. A subsequent visit to the gauging station showed that the clock had indeed stopped. It is noteworthy that the stoppage was not caused by an instrument malfunction but by a "cockpit error" by the person servicing the instrument on a previous visit.

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DCP Failures

DCP 6260 failed in late 1973. At first the failure was attributed to an error in reconnecting the platform at a new temporary location but it is now believed that the failure was caused by lightning or some other phenomenon. A significant portion of the programmer board was burnt up and there was some damage to the analogue board. It was also discovered during the check out of the platform, that there were many failures in the transmitter board although these were not visible to the eye. Photos of the programmer board are shown in Appendix I.

The DCP antennas were exposed to heavy snow loads in some cases and strong winds (in excess of 100 km/hr.) in others. No DCPs stopped transmitting because of antenna damage, however, the antenna ground plane for 6126 was damaged by snow loading in the winter of 1973-74. No damage occurred in 1972-73 at the same site. It seems likely that the damage was caused by snow loading on the guywires rather than the ground plane itself. Unless an antenna will be exposed to strong winds, it would be advisable not to use guywires.

CONCLUSIONS

The original intention of the Water Survey of Canada in participating in the ERTS DCS experiment was to determine if reliable water level data could be retransmitted twice daily from an isolated location on a near real time basis. It is apparent that the experience since the launch of ERTS-1 has amply demonstrated the technical feasibility of satellite retransmission, at least from low orbiting spacecraft.

The General Electric DCP has proven to be a versatile, rugged piece of hardware and has surpassed original expectations. No serious interfacing problems have been encountered. The quality of reliable data gathered by the ERTS DCPs has proven very useful for water resources management and hydrometric field operations.

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Some specific uses of the data obtained from the nine gauging stations having ERTS DCPs were:

a) A Provincial Water Resources Agency used ERTS data for preparation of flood forecasts on a major river system.

b) A Hydro-electric company used ERTS data for regulation of reservoirs on an international river.

c) A river transportation company used water level forecasts prepared from ERTS data to determine barge loadings during an eight week shipping season.

d) Levels of a large northern lake obtained by ERTS are used along with data from other sites to prepare a monthly bulletin on runoff conditions in Canada.

e) The installation of an ERTS DCP at a newly established gauging station enabled Water Survey of Canada personnel to schedule visits to the site so that the stage-discharge relationship for the station was determined more quickly than normal.

f) DCS data were used to fill in a period of record during a time when the water stage recorder was not operating. Normally discharges during such a period would have to be estimated.

g) DCS data from one site indicated a sensor malfunction thus enabling Water Survey field personnel to be prepared to carry out repairs on the next trip to that site.

h) During a period of intense rainstorm activity, real time DCS data showed that river discharges were not unduly affected thus eliminating the need to charter a helicopter for a trip into the gauging station.

The economic, social and environmental benefits of timely, accurate streamflow data have been demonstrated many times over in Canada and other countries. Unfortunately, these analyses tended to express the benefits and costs in terms of "net human benefit" so it is difficult to extract benefits and costs for the data gathering agency.

On the basis of experience to date, it can be stated that, where near real time data are required from remote areas, the data can be most economically obtained by satellite retransmission rather than radio systems. Also in populated areas, satellite retransmission is very competitive with telephone systems if a ten year operating period is considered.

In those cases where streamflow data are collected for archival purposes, the use of satellite retransmission systems would result in increased accuracy of records because visits to a gauging station would be more timely and data loss would be reduced. Operating costs could be lowered because of fewer visits to gauging stations. Alternatively, the costs could increase because of more frequent visits to take measurements at the best times and to repair sensors as soon as failure occurs. These benefits and costs should be considered along with the capital and operating costs of the DCPs. This question should be examined on a rigorous basis before any definite conclusions are drawn.

FUTURE ACTIVITIES

One effect of the ERTS Data Collection System has been to create an impetus for further work on operational satellite data collection systems in the United States, Canada and other countries. The success of ERTS-DCS has convinced a number of potential users of satellite retransmission systems of the usefulness of this technology well in advance of the commissioning of any operational systems in this country.

To assess the benefits of an operational satellite retransmission system, a network of 28 DCPs at Water Survey of Canada gauging stations is proposed. To implement these plans, an order for 19 ERTS-GOES convertible platforms has been placed with Ball Brothers Research of Boulder, Colorado. These platforms will be used with ERTS-1 and succeeding ERTS spacecraft as well as with the SMS-GOES system.

The principal objective in establishing a larger network of DCPs will be to approximate an operational situation. In this way, it will be possible to quantify the benefits of retransmitted data. It should be possible to develop figures for operating costs of this larger network. Also the use of the platforms may make it possible

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to reduce the number of visits by Water Survey of Canada personnel to the remote gauging stations or to make the visits at more opportune times and thus produce better data.

The sites will be selected on the basis of requirements for real time water resources data for water management purposes. The data will always include water level readings, and in some case precipitation, temperature and snow pillow, DCP battery voltage, "ice-out" indication, water velocity, ice thickness, and water stage recorder operation data will also be transmitted.

The CCRS is presently studying the possibility of receiving and demodulating ERTS DCS at the Prince Albert, Saskatchewan ground station. Receiving data at this location should result in an increased number of messages from more orbits of the satellite being available to data users.

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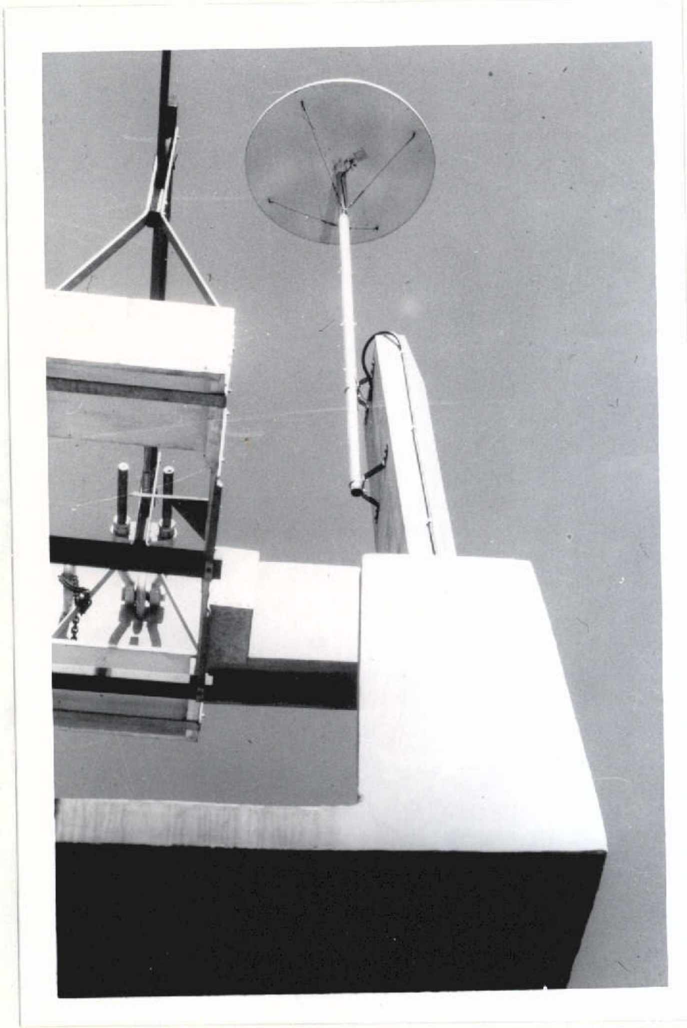
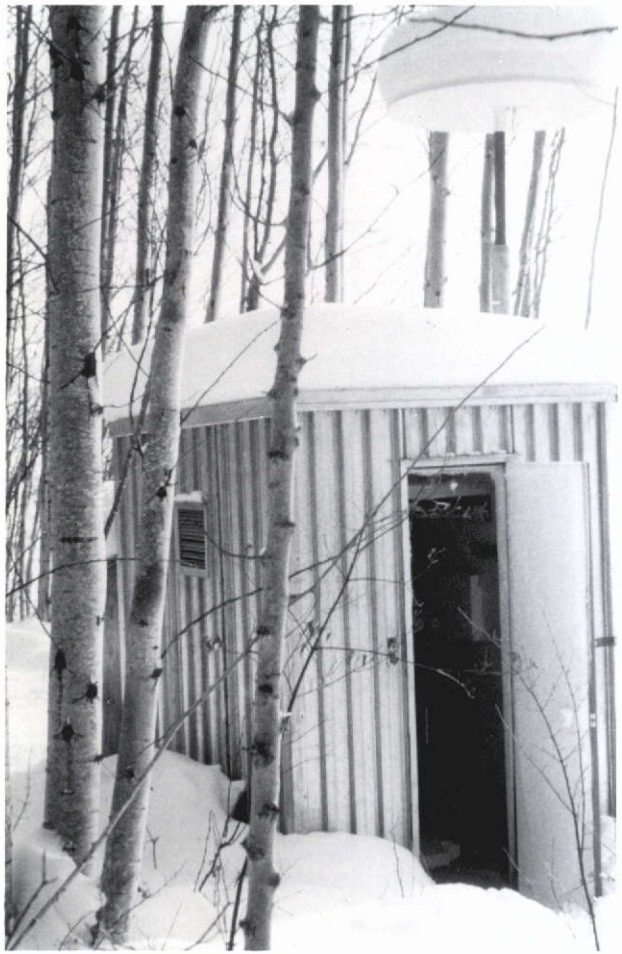
APPENDIX I

Photo Credits: K.F. Davies, Photo 4; W.L. Edwards, Photo 2; R.A. Halliday, Photos 1, 5, 7; K.D. Loeppky, Photos 3, 8; D. McFadden, Photos 11, 13, 14; I.A. Reid, Photos 9, 10; F.M. Sullivan, Photo 6; and B. Tippin, Photo 12.



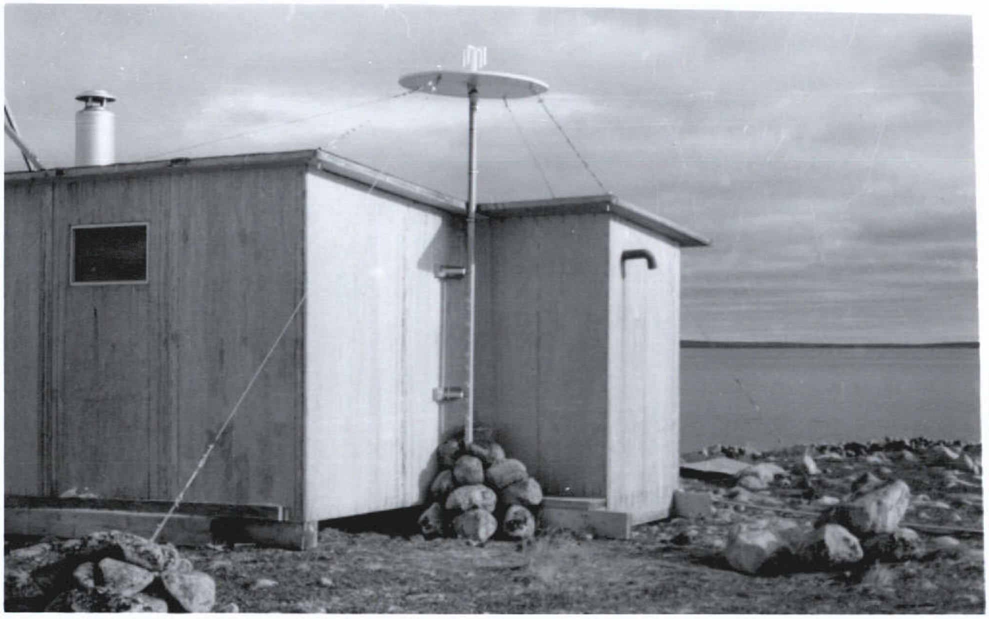
1. Rideau River at Ottawa test site.

2. Illecillewaet River at Greeley



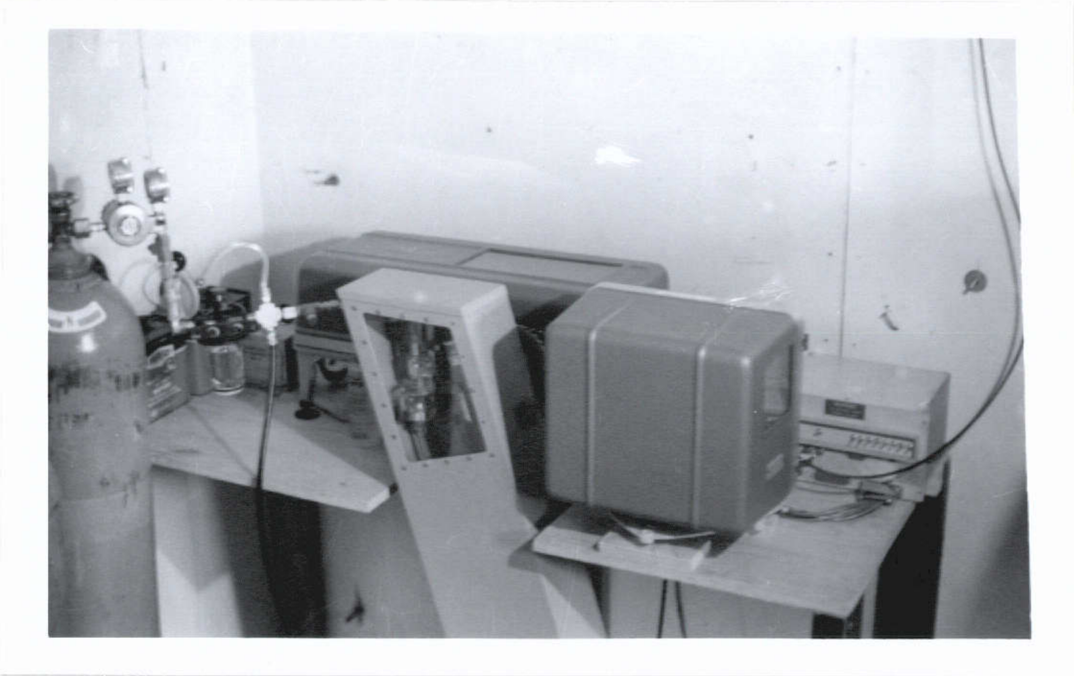
3. Mackenzie River at Fort Simpson

4. Mackenzie River at Sans Sault Rapids

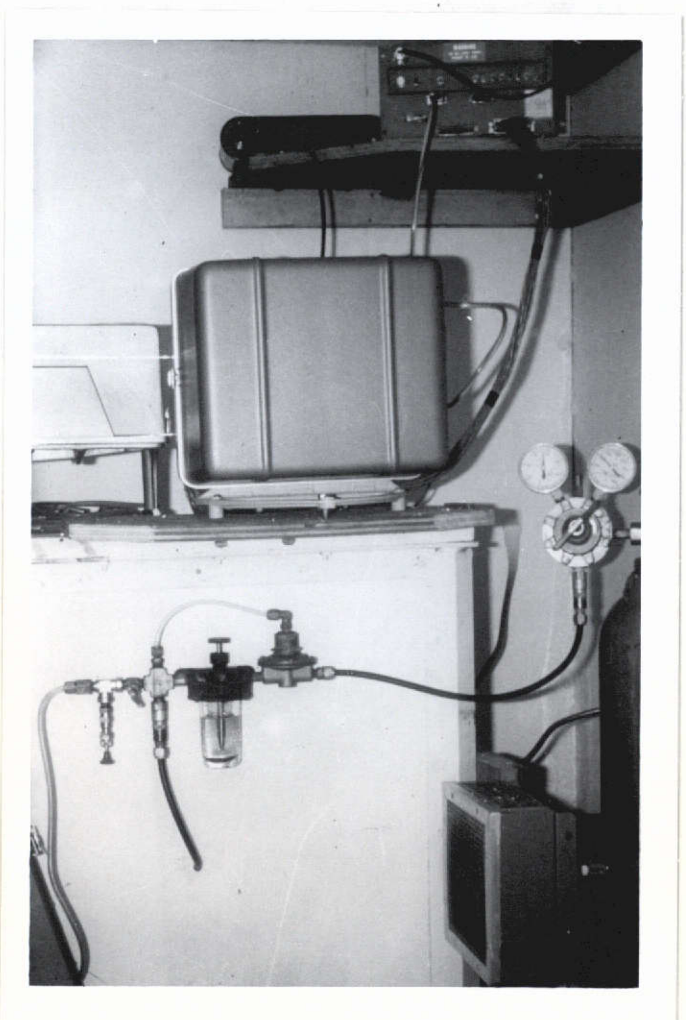


5. Kazan River at Outlet of Ennadai Lake

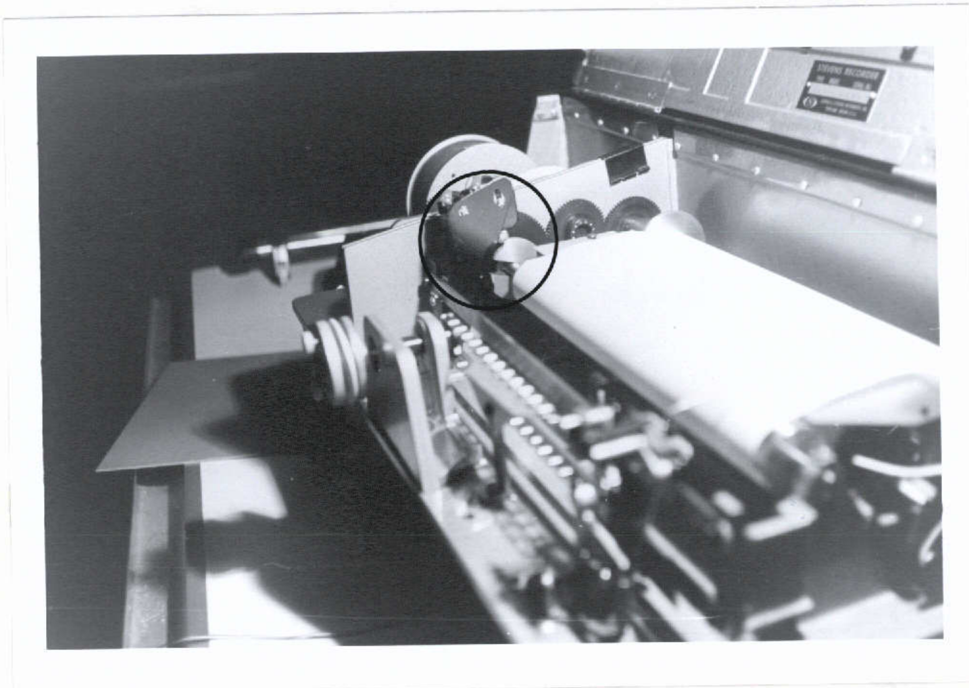
6. Winisk River below Asheweig River Tributary



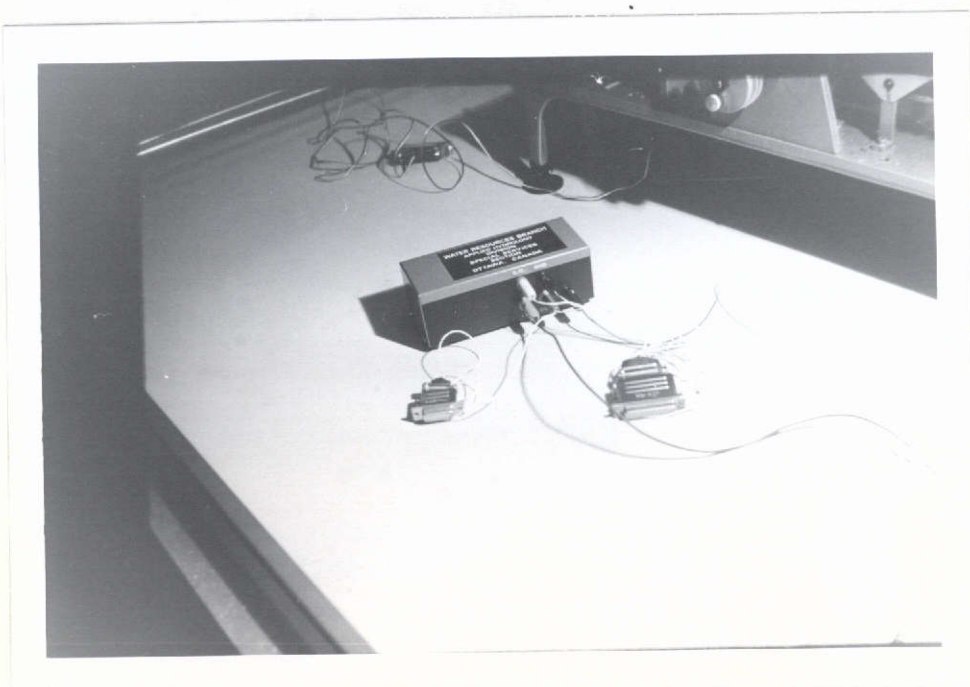
7. Interior - Kazan River Installation



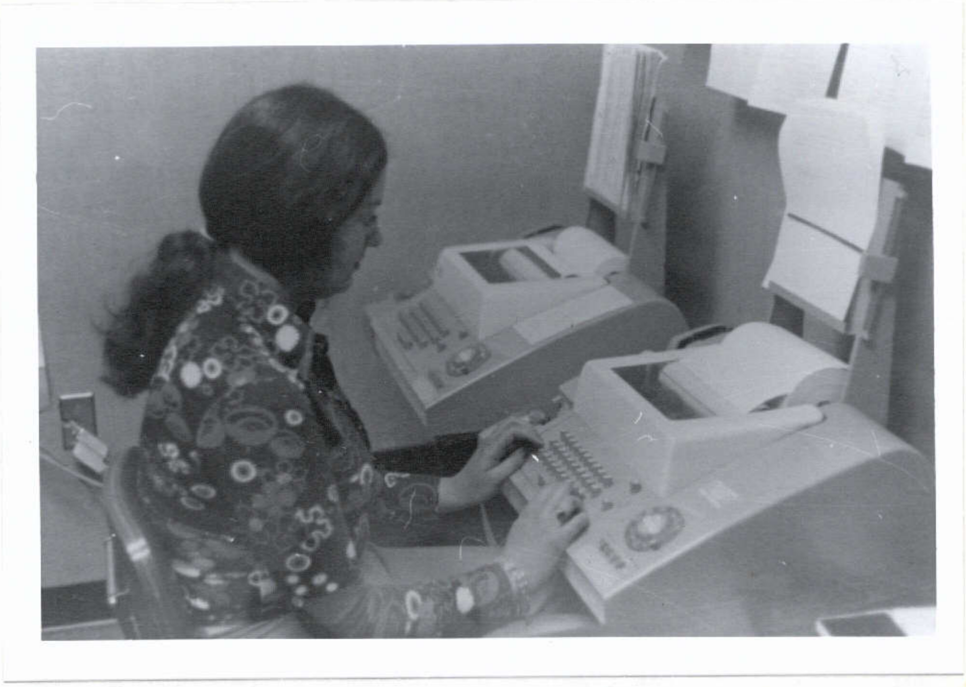
8. Interior - Fort Simpson Installation



9. Recorder Operation Sensor

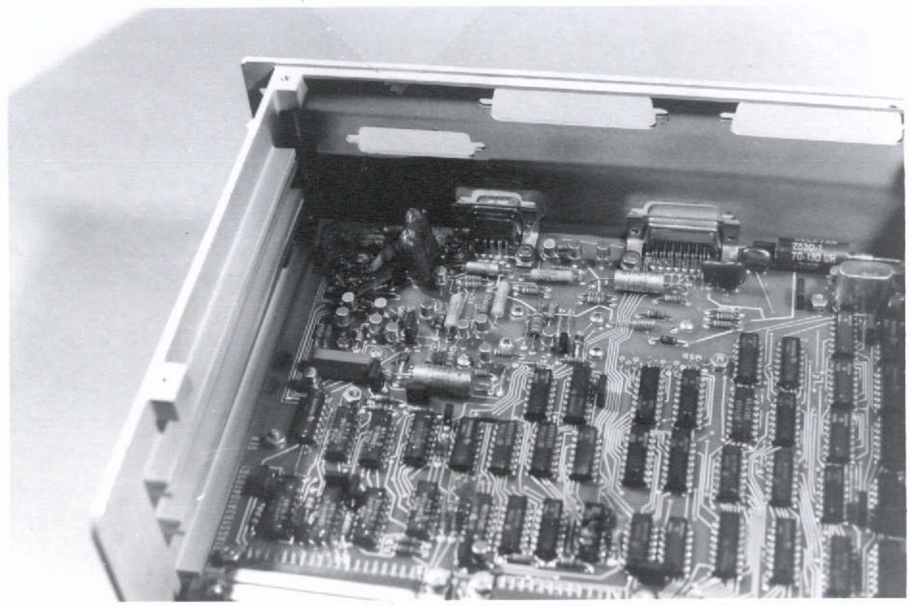


10. Battery Voltage Sensor

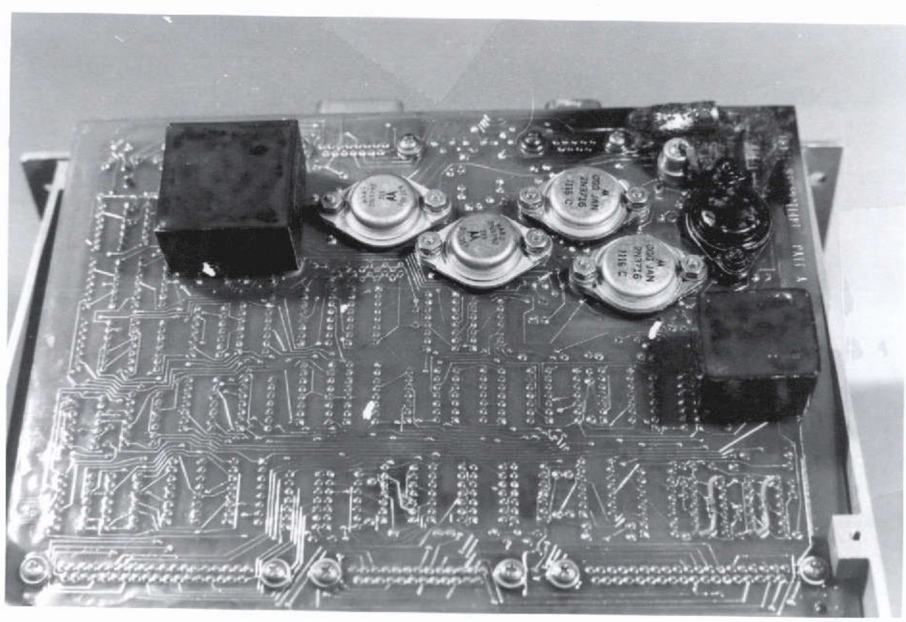


11. Receipt of DCS Data by Telex

12. Damage to antenna ground plane



13. DCP 6260, damage to programmer board (top)



14. DCP 6260, damage to programmer board (bottom)